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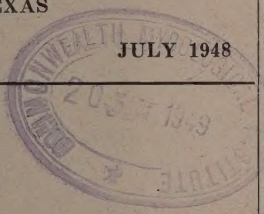

The Control of Transit and Storage Decays in Texas Lemons

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CONTENTS

Page

Literature Review 5

Experimental 9

Tests With Soaps and Fruit Cleansers 9

Stem-end Treatments With Chemicals 10

Fruit Dip Treatments With Chemicals 11

Borax 13

Sodium Metaborate (Metbor) 13

Sodium Ortho-phenylphenate (Dowicide A) 14

Ineffective Chemicals 17

Diphenyl Tissue Wraps as Supplemental Treatment 17

The Control of Penicillium (Green Mold) Decay 19

Diphenyl-Impregnated Tissue Wraps for Green Mold Control.. 20

Fumigation With Nitrogen Trichloride (Decco) 21

Recommendations 22

Literature Cited 24

Preface

Citrus fruits, particularly lemons and early oranges, are subject to transit and storage decays. Sometimes when conditions are very bad, decays range up to 85 percent 3 weeks after harvest. Stem-end decay caused principally by the fungus *Diplodia natalensis* is the principal source of loss from midsummer to late fall in the Lower Rio Grande Valley. The green mold, *Penicillium digitatum,* and to a less extent the blue mold, *P. italicum,* are the leading causes of decay in the winter months.

Experimental work conducted on lemons at the Lower Rio Grande Valley Station (Substation No. 15) from 1939 to 1946 has shown that these losses can be controlled, usually from 0 to 5 percent decay, by chemical dip treatments. Materials found effective for the dip treatment are sodium metaborate (Metbor) at 5 percent concentration, and sodium ortho-phenylphenate (Dowicide A) at 1.2 percent concentration, each with specific qualifications mentioned in the body of this bulletin.

The effectiveness of these chemicals in periods of high incidence of decay is increased by wrapping the fruits in diphenyl-impregnated tissue wraps. Control in such periods can also be increased by following the chemical dip treatment with exposure to 0.03 parts per million nitrogen trichloride gas in the ethylene gas coloring room, or even in the car after loading (Decco process).

The series of experiments reported herein have consistently shown that the serious losses frequently occurring in the shipments of non-treated fruit can be avoided by proper use of the recommended treatments.

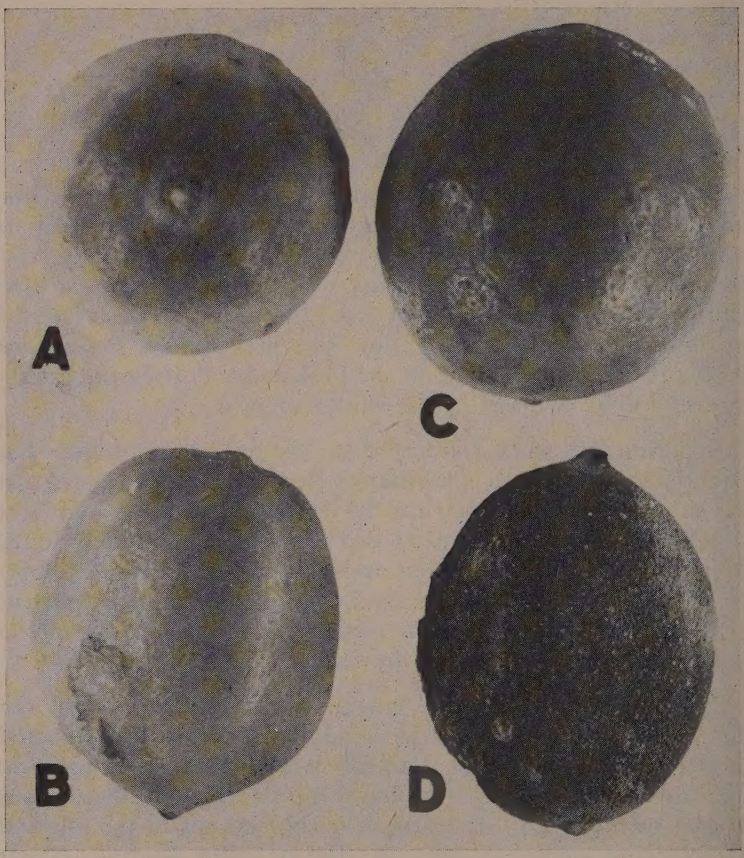

Figure 1. Stem-end rot *(Diplodia natalensis)* in Meyer lemons. *A*, an early stage, about 24 hours after the first symptom; an irregular tan discoloration, is barely evident extending ¼ to ½ inch from the stem button. *B*, a more advanced stage with about half the fruit discolored in irregular bands which are usually slightly flattened. *C*, the entire fruit is involved, but the fruit is still intact; up to this stage there is no surface mold on the fruit. *D*, the fruit is entirely black and somewhat mummified; at this stage the spore-bearing bodies of the fungus may frequently be found imbedded in the rind in the form of very small globular bodies filled with the white spore mass.

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Stem-end rot, due chiefly to the fungus *Diplodia natalensis,* has long been the source of serious loss to citrus growers in the Lower Rio Grande Valley of Texas. Lemons, mostly of the Eureka and Meyer varieties maturing in summer and fall, are particularly subject to these losses (see Figures 1 and 2). Frequently, however, losses are also encountered in early and late oranges and occasionally in grapefruit. Blue and green molds (*Penicillium italicum* and *P. digitatum,* respectively) sometimes cause large losses in transit and storage during winter (see Figure 3).

Decay in citrus fruits has remained a serious problem to the commercial packer and shipper, to the broker at the terminal markets, to the retailer and to the ultimate consumer in spite of the routine application of standard preventive measures. It is indirectly serious to the grower in that any shipment of fruit from his territory that develops a high percentage of decayed fruits causes consumer ill-will and prejudice against fruit from that locality for a prolonged period, even though later shipments may be sound.

This bulletin reports the results of experiments performed by the senior author from 1938 to 1942 and by the two authors jointly from 1943 to 1946, directed toward the control of these losses in lemons. A few tests with oranges are also included.

LITERATURE REVIEW

It is well established (7) that two distinct fungi, *Diplodia natalensis* Pole-Evans and *Diaporthe citri* (Faw.) Wolf, produce stem-end rot, and that the symptoms produced are very similar—a leathery, pliable decaying area encircling the button or stem end, buff colored to brown in color, gradually enlarging in area and turning darker in color until the entire fruit is involved. With *Diplodia,* the rot culminates in a black color and complete mummification of the fruit. It is known (2, 21, 23, 24) that with both fungi, one stage is on dead wood in the tree, where, during a moist period, spores are produced abundantly and are deposited on the fruit. Under favorable conditions the spores will germinate, and the hyphae

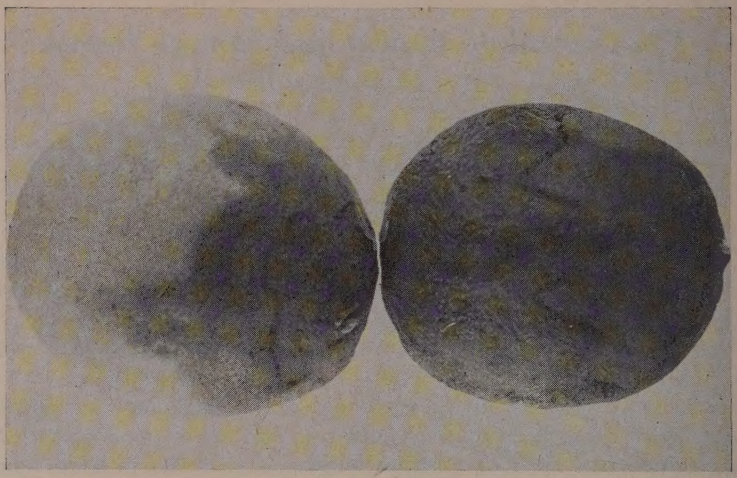

Figure 2. Stem-end rot *(Diplodia natalensis)* in Meyer lemons showing the advance of decay. The dark lines indicate the margin as it was 42 hours before the photograph was taken. The fruits were held at room temperature (minimum, 76°, maximum, 96° F.) September 10 to 12, 1947.

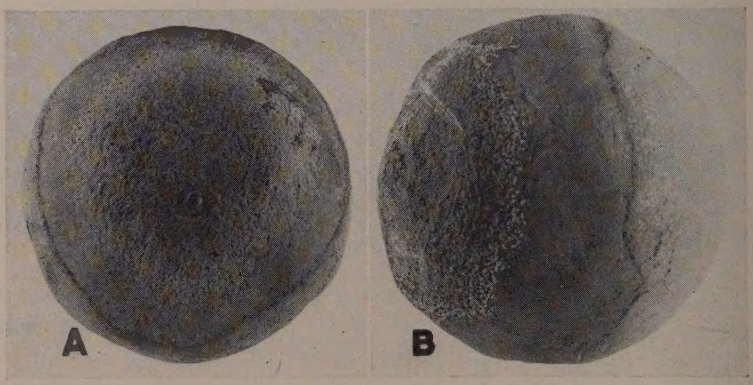

Figure 3. Blue mold *(Penicillium italicum)* and green mold *(Penicillium digitatum)* on Valencia oranges. *A*, blue mold; note the dark spore-bearing central region surrounded by a rather narrow white belt of fungus mycelium, then a narrow zone of water-soaked rind, the advancing edge of which is indicated by the dark line drawn on the fruit. *B*, green mold; aside from the difference in color, this being olive green instead of blue, this usually has a broader band of white mycelium, and a much broader band of water-soaked rind surrounding the mold. The blue mold, known also as blue contact mold, has a greater tendency to spread from fruit to fruit in the container.

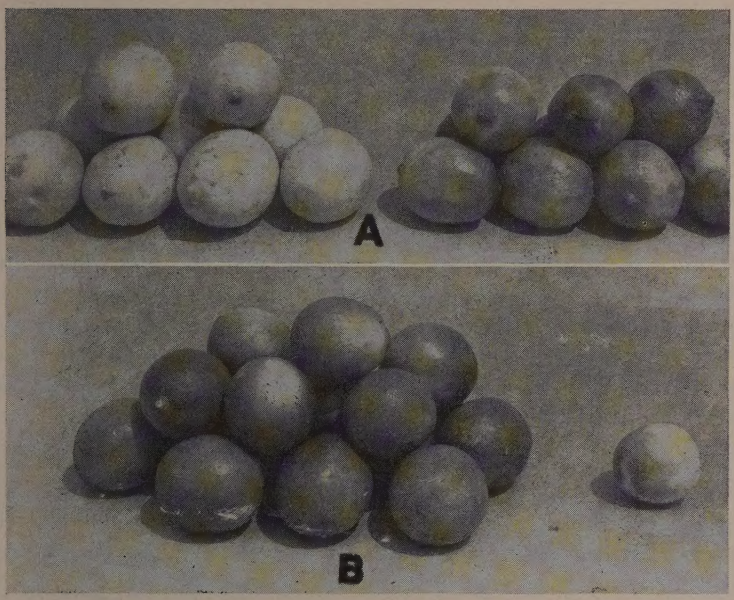

Figure 4. Stem-end rot *(Diplodia natalensis)* in Meyer lemons, showing relative proportions of sound and decayed fruits 10 days to 2 weeks after harvest in non-treated and treated lots of fruit. *A*, non-treated, 50 percent decay (right). *B*, illustrating a typical result from one of the recommended treatments, with only 5 percent decay. Frequently much lower percentages than this are attained.

will penetrate into the fruit tissues through the stem or through the rind in the vicinity of the stem, thereby initiating the rapidly developing fruit decay. Winston (21) has dealt comprehensively with the factors influencing fruit decay. Pruning off all dead wood in the orchard reduces the sources of infection and the problem of control (23). Spraying the trees with a fungicide likewise reduces the amount of potential infective material and thereby reduces the incidence of decay (23). Pulling the fruit, instead of clipping it, is said (23, 24) to reduce the amount of stem-end rot, but possibly to increase the blue and green molds (10) because of breaks in the rind. Dis-buttoning (removing the stem base after harvest) also reduces decay (11, 22, 24) but thus far no practicable means have been developed for doing this uniformly and economically in time to be of value. The ethylene gas degreening process causes the loosening of buttons, but by the time this processing is completed much infection has already occurred. As is well known, exposure in the coloring room predisposes the fruits to stem-end rot, since it

acts as a favorable incubation chamber for the fungi causing decay; ethylene gas even appears to stimulate the germination of Diplodia spores (2, 3).

Extensive experimental work for at least 30 years has been done on the treatment of citrus fruits at the packing house for prevention of decay. Borax was found as early as 1923 (1, 8) to be not only an effective fruit wash but also to have disinfectant qualities that resulted in reduction in stem-end rots and blue and green mold rots. For greatest effectiveness it had to be used in a warm, saturated solution (about 110° F.) which permitted a higher concentration than is possible in a cold solution. Sodium metaborate (Metbor) was found to be almost as effective in cold water at a 4½ or 5% concentration (20).

Brooks (2, 3) and Miller *et al.* (12) give the results of extensive experimental work with sodium ortho-phenylphenate (Dowicide A) concluding that 1.2% is the most effective concentration, that the fruit must be rinsed after treatment to avoid chemical injury, and that stem-end decay control was probably somewhat better than with borax. Brooks (2) reports that including 1.2% Dowicide A in the water phase of a water-wax emulsion at 100° F. caused no injury and gave good control. Childs and Siegler (4, 5, 6) also gave a concise but comprehensive review of the facts known about citrus fruit decays, and detailed accounts of experimental work with the organic chemicals thiourea, thioacetamide, 2-aminothiazone and quinosol (8 hydroxyquinoline sulfate). The first two at 5% aqueous solution and quinosol at 8% reduced decay from 40% to 2% or less. Combinations of these treatments with a waxing process were developed and gave satisfactory results. The practicability of commercial treatments with any of these newer chemicals remains to be solved. Work with diphenyl (10, 13, 14, 15, 16, 19) has indicated that this material used by special methods may fill a place in the handling of citrus fruits. Fruit wrapping tissues and box liners impregnated with this chemical reduce decay to a marked degree. They are already in extensive use in some fruit packing houses. In a separate paper (17) the authors reported remarkably good results in tests with nitrogen trichloride, and with various chemical treatments followed by nitrogen trichloride gas treatments.

A new approach to control of decays was recently presented by Siegler and Childs (18) with water-insoluble chemicals—diphenyl sulfoxide, benzhydrol and phenylurethane in isopropanol. While fairly good control of stem-end rot was obtained, commercial practicability is not yet demonstrated.

EXPERIMENTAL METHODS

The earlier tests were directed largely toward finding a promising treatment that might prove superior to the standard commercial treatments, which were far from satisfactory. Attempts were made to improve the efficiency of borax and of sodium metaborate by additions of iodine or other materials. In testing new materials, a standard treatment such as with borax was frequently included as a basis of comparison.

Each fruit sample for treatment consisted of 200 fruits in most of the tests. To reduce sample variability about 10 fruits were taken from each of about 20 field boxes as they were brought in from the grove. Applications were made for the stem-end treatment either by means of a stamp pad soaked with the chemical in solution, on which the stem end of the fruit was pressed with a circular motion, or by a small brush which thoroughly wet the stem or button and the shallow cavity surrounding it. For the complete fruit dip the fruit, in a mesh bag, was immersed directly into the container of solution for 2 minutes with constant agitation. Then the fruit was drained and poured into crates. If rinsing was required to prevent chemical injury, it was done while the fruit was still wet, usually with a hose. The crates of treated fruit were stacked, labeled and trucked into the ethylene gas chambers for coloring (degreening). The period in the coloring room varied from 7 days early in the season when all fruits were completely green, to 2 days or even less when they were already nearly yellow. Degreening was unnecessary in some late-season tests with well-ripened fruits.

Records of decay development were usually made twice; first at the time of removal from the coloring room when the fruit was usually wrapped and packed according to standard procedures, and again after storage at warehouse temperature for about 14 days. Records were usually kept separately on duplicate 100-fruit samples. The final counts only for the total decay after harvest are reported in this bulletin as the average for the duplicate lots. Each table is a condensation of the results from several different experiments, as indicated by the dates of treatments.

Tests With Soaps and Fruit Cleansers

Several fruit cleansing materials were tested for their effectiveness in preventing fruit decay. The results are summarized in Table 1 which includes comparable non-treated lots.

It appears obvious from this table that, for the more important fruit rots, the washing compounds alone, in reasonable concentration,

Table 1. Effects of soaps and fruit washing compounds on decay in Meyer lemons

Date of treatment	Duration days* A	Duration days* B	Material used	Concentration, percent	No. of fruits	Decay, percent: Stem-end	Decay, percent: Other
9/20/38	0	20	Brownsville soap	1	100	64.0	.....
12/31/42	4	9	WCC fruit cleanser	1	100	19	8
1/14/43	0	13	WCC sulfamatachloride	0.25	100	19	15
1/14/43	0	13	WCC sulfamatachloride plus fruit cleanser	0.25			
				0.1	100	25	14
9/—/38	5	8	Wyandotte fruit cleanser	2†	25	4	.....
9/20/38	0	20	Wyandotte fruit cleanser	1	100	60	.....
9/20/38	0	20	Zelco fruit cleanser	0.4	100	67	.....
9/20/38	0	20	Zellner fruit cleanser	0.133	100	83	.....
9/20/38	0	20	Zellner fruit cleanser	0.25	100	60	.....
			Checks	.....	625	31.0	15

*A—time in coloring room; B—time held at room temperature.
†Chemical injury and wilting were severe at this concentration.

are not effective in preventing decay. It is necessary to use a strong, penetrating disinfectant. This report is not meant, however, to be derogatory to the cleansing agents tested, as such.

Stem-end Treatments with Chemicals

Some of the early exploratory tests showed that a stem-end treatment alone with certain disinfectants gave good control of stem-end decay (9). A number of tests with different chemicals were conducted by this method.

Only two of the many materials tested showed some promise. Fruit treated with diphenylamine 10% in a mixture of 95% alcohol and acetone (90 to 10) showed no decay while the corresponding check showed 28%. This material at 1% or less, however, showed no value, with stem-end rot as high as 90% in some of the trials. Tetrachloro-para-benzoquinone (Spergon) saturated in a light mineral oil to which 10% lanolin had been added to increase its penetrating power, completely prevented decay; and as saturated in the alcohol-acetone 80 to 20 mixture reduced stem-end rot to 4% while the check showed 10%. Diphenylamine is an effective disinfectant used in veterinary medicine. Spergon is one of the organic seed disinfectants.

Many other chemicals were found to be ineffective, or nearly so. The incidence of stem-end rot ranged from 10 to as high as 88%. The ineffective chemicals are listed below as a matter of record.

Alcohol, denatured.
Benzoic acid, from 0.1 up to 6% in alcohol (severe chemical injury at 4 and 6%).
Borax, 10% in alcohol-glycerin 50-50.
Boric acid, 2% in alcohol.

Hydroxyquinoline, from 0.01 to 0.1% in alcohol, alcohol-glycerin and alcohol-acetone, 90-10.
Iodine, 0.1% in alcohol.
Malachite green, 0.1 and 0.05% in water and 50% in alcohol.
Mercresin, 0.1% aqueous and 0.02 and 0.04% in 10% acetone.
Phenol salicylate, 1 and 4%.
Salicylic acid, 0.1, 0.5 and 1% in alcohol and 1% in alcohol-acetone.
Undecylic acid, 0.01 and 0.05%.
Zinc acetate, 0.5% in 50% alcohol.
Octylphenol, 1% in alcohol-acetone.

The corresponding checks ranged from 19 to 86% decay.

The stem-swab method of treating fruit has not been considered seriously for commercial use on citrus fruit as it has on melons. It is, however, a quick means of testing new chemicals that may be available only in small quantities. Furthermore, such tests may provide a lead to materials for treatment by the entire-fruit-dip method. Should the stem-swab treatment prove effective, it may then be followed by experimental fruit-dip treatments with the same and closely allied chemicals.

Fruit Dip Treatment with Chemicals

The preferred method of fruit treatment with a chemical in liquid form for decay control is the entire-fruit dip. The fruit is brought in from the field in lugs, dumped into the large tank containing the chemical in solution and, after about 2 minutes soaking, is carried out of the solution by endless chain devices to further processing. The coloring (degreening) process when required must be given prior to the application of any waxing treatment. Consequently, treatment for decay prevention before coloring is an extra process requiring complete handling of the fruit—dumping, dipping, reboxing, stacking and trucking to the coloring room—before the regular preparation-for-packing procedures are applied. Most of the treatments given in this series of experiments from 1938 to 1946 were by the entire-fruit-dip method.

Borax and other materials containing boron, particularly sodium metaborate (Metbor) have probably been used more extensively in the past several years for the control of various kinds of decay in citrus fruits than any other materials. One or the other was used frequently in the series of tests reported in this paper, either as a direct test to determine its value under Lower Rio Grande Valley conditions, or as a basis of comparison with other materials. Results obtained with borax and sodium metaborate are given in Tables 2 and 3.

Table 2. Results of fruit-dip treatments in solutions of borax for decay control in lemons

Date of test	Test period: Color room	Test period: Room temp.	Concentration and conditions	Treated fruit: No. of fruits	Treated fruit: Decay, percent: Diplod.*	Treated fruit: Decay, percent: Penic.†	Corresponding check: No. of fruits	Corresponding check: Decay, percent: Diplod.*	Corresponding check: Decay, percent: Penic.†
	days	days							
9/39	5	16	8.0%, 2 min. dip, 116-120° F	50	6.0	.....	50	86.0	.....
8/41	7	7	4.5%, room temperature	218	4.6	.....	217	17.5	.....
8.41	7	7	5% + Iodine in KI‡ .02%, room temperature	301	6.0	.....	.....	.....	.....
8/41	7	7	5% + Iodine in KI .02% + Tergitol .5%	254	7.1	.....	.....	.....	.....
8/41	7	7	5% + Iodine in KI .04%, room temperature	225	1.8	.....	.....	.....	.....
9/42	0	15	4.5%, room temperature	100	1.0	.....	200	9.5	.....
9/42	0	15	5% + Iodine in KI .03%, room temperature	100	2.0	.....	.....	.....	.....
11/43	0	13	4%, room temperature	100	3.0	29.0	200	13.5	19.5
11/43	0	13	4% + Iodine in KI .03%, room temperature	100	5.0	23.0	.....	.....	.....
11/45	5	14	5%, 2 min. dip, 105° F	200	11.5	0.5	200	28.5	6.0
Weighted averages									
Total fruits and average decay, all tests				1648	5.3	.....	867	21.2	.....
Three room-temperature borax treatments				418	3.4	.....	617	13.6	.....
Five treatments at room temperature, with supplements				980	4.8	.....	617	13.6	.....

Diplodia natalensis.
†Mostly *Penicillium digitatum.*
‡Potassium iodide.

Borax

The three cold (room temperature) saturated-borax treatments shown in Table 2 gave very good control of stem-end rot with an average of only 3.4% decay, while the corresponding checks averaged 13.6%. Five treatments at room temperature with additional materials gave 4.8% decay, with the same checks as before. The addition of iodine at 0.02 to 0.03% did not give any improvement. Iodine at 0.04% was beneficial in a single test. Borax treatment of lemons has a slight corrosive action on the rind of the fruit that tends to reduce its brightness. It also hastens the wilting or shriveling of the fruit. This may be overcome in part by waxing as soon as the fruit is yellow. In a single case in which the borax was used at a high concentration (8% in water heated to 116° to 120° F. in line with some Florida usage), there was 6% decay when the corresponding check showed 86% decay 21 days after harvest. However, there was extreme wilting in the thin-skinned Meyer lemon used, and the treatment must be considered impracticable for that variety at least. In general, the room temperature treatment with a saturated solution would appear to justify its recommendation for the control of stem-end rot in late summer and early fall seasons when this decay is most active. Borax treatment did not give satisfactory control of green mold in the November tests.

Sodium metaborate (Metbor)

Sodium metaborate, in 14 miscellaneous tests in which the material was used as a basis of comparison with newer materials from September 1939 to January 1943, consistently reduced stem-end decay as compared with checks, and usually reduced green mold. The poorest showing was made with .4% solution on a lot of 50 fruits in September 1939, when 52% stem-end decay developed, as compared with 86% in the check. Better results in general were obtained at 5%. The reduction in 6 treatments with 850 fruits was to an average of 6.7% decay as compared with 15.5% in the checks. The addition of iodine at 0.02% (dissolved in a solution of potassium iodide) appeared to bring about some increased reduction in stem-end rot, thus justifying further experimentation with this material. Reductions in green mold were not consistent. In some cases the incidence of this decay was actually greater in the treated than in the non-treated lots.

An effort was made to determine the proper role of sodium metaborate for the treatment of citrus fruits in Texas in an extended series of identical treatments conducted at approximately monthly intervals from July to December 1943. The chemical was used at room tempera-

ture, or in some cases, at approximately 85° F., 70° F. and 65° F., in near-saturated solution, mostly 5%. Tests were run in the same series with Vatsol OS added as a wetting agent adapted to use in alkaline solutions, with and without iodine. In this series, 33 lots of 200 fruits each were treated. Since no consistent difference was evident due to either temperature or to month of application, the results are condensed into a single table, Table 3. Results with the Eureka and Meyer varieties are recorded separately.

Table 3. Results of sodium metaborate treatments for the control of decay in lemons, July to November 1943

Variety	Treatment	Treated fruit			Corresponding checks		
		No. of fruits	Av. decay % and range‡		No. of fruits	Av. decay % and range‡	
			Dipl.*	Penic.†		Dipl.*	Penic.†
Eureka	5%, 2 min., 85° F.....	1200	22.6 (3.5-37.5)	3.9 (0.5-6.5)	1000	39.6 (8-68.0)	0.8 (0-2.5)
Eureka	5%, + Vatsol, 0.1%.....	1200	19.0 (5.5-35)	2.5 (0-7.0)	1000	39.6 (9-68.0)	0.8 (0-2.5)
Eureka	5% +Vatsol +Iodine 0.02%	1200	14.0 (4.5-27)	9.1 (0-47.1)	1200	35.9 (8-84)	8.1 (0-47.1)
Meyer	5%, 2 min.....	1000	5.8 (0.5-14.7)	5.1 (1-13.5)	800	40.8 (16.0-69.5)	2.2 (0-4)
Meyer	5% + Vatsol.....	1000	14.8 (3-33)	5.4 (1-9.0)	800	40.8 (16.0-69.5)	2.2 (0-4)
Meyer	5% +Vatsol +Iodine 0.02%	800	8.5 (2.5-15.5)	3.8 (.5-8)	800	34.5 (16-53)	3.4 (0-8.5)

Diplodia natalensis.
†Mostly *Penicillium digitatum.*
‡Range is shown in parentheses below the average.

Sodium metaborate at 5% did not give satisfactory control of stem-end rot in Eureka lemons. There was 5.8% stem-end decay with the thin-skinned Meyer variety as compared with 40.8% decay in the corresponding checks. There was no substantial benefit from the addition of the wetting agent, Vatsol, or of Vatsol and iodine. Recommendation of the use of 5% Metbor for the control of stem-end decay in Meyer lemons during the summer and fall months would be justified.

Sodium ortho-phenylphenate (Dowicide A)

Preliminary tests conducted in 1942 and in January 1943 with sodium ortho-phenylphenate indicated good control of decay in lemons. It was very satisfactory at 1.0% with reduction to 1 and 2% stem-end decay, but gave poor control of green mold. In line with results reported elsewhere (3, 12), 1.2% was adopted as the standard concentration for an extended series of tests conducted at approximately monthly intervals beginning in July 1943. It had

already been shown that this treatment alone resulted in chemical burning of the rind in spots where the chemical dried; and this was further verified by special trials in the extended series. Consequently, it was found necessary to rinse the fruits with tap water after treatment. The addition of formaldehyde to the treatment solution did not eliminate this burning as it did in Florida tests (12), and rinsing was also necessary to prevent injury. Results of all tests with sodium ortho-phenylphenate are shown in Table 4.

Results in the control of stem-end decay with sodium ortho-phenylphenate were extremely erratic, with decay ranging from 0 to 54%. The treatments did not give satisfactory control with Eureka lemons in a comparable summer and early fall series of tests with immature fruits that required a considerable period in the coloring room. The average of 2 treatments with straight Dowicide A showed 48.2% stem-end rot; 3 treatments in late summer and fall with Vatsol added showed 17.8%, which is a considerable reduction and indicates a value for the added wetting agent. The corresponding 2 checks for each showed 76.0% and 40.7% stem-end decay, respectively. The best of these treatments, Dowicide A with Vatsol, did not show sufficient control to be considered practicable.

Results were better with the Meyer lemon. There was an average of 9% stem-end decay in October and November treatments as compared with 57% decay in the checks. With Vatsol added in August, September and October treatments, there was an average of only 1.8% stem-end decay as compared with 31.2% in the checks. Here again the added wetting agent appeared to have real value.

Taking the two varieties together, the average stem-end decay in the critical late summer and fall months when losses are normally greatest, was reduced by Dowicide A to an average of 8.2% as compared with 48.7% in the checks. In the absence of a consistently better treatment, then, on the basis of this evidence, the use of Dowicide A with a wetting agent added would appear to merit recommendation. The situation is complicated, however, by the need for rinsing, which involves an additional step in the processing.

Attention should be called to the single case in November 1944 when Dowicide A was used at 2% concentration on Eureka lemons with reduction of stem-end rot to 0.5% when the check showed 58.5%. There was severe burning with this treatment. Unfortunately, a corresponding duplication of the treatment with rinsing was not included in the test.

Table 4. Results of fruit-dip treatment in solutions of sodium ortho-phenylphenate (Dowicide A) for decay control in lemons. Treatment prior to coloring (de-greening)

Date of test	Color room	Room temp.	Variety*	Concentration and conditions	Treated fruit			Corresponding checks		
					No. of fruits	Decay, percent		No. of fruits	Decay, percent	
						Diplod.	Penic.		Diplod.	Penic.
	days	days								
12/42	4	9	M	0.5%, not rinsed‡	100	9.0	13.0	200	17.0	10.5
12/42	4	9	M	1.0%, not rinsed‡	100	0	5.0			
1/43	0	13	M	1.0%, rinsed	100	1.0	25.0	200	13.5	19.5
1/43	0	13	M	1.0%, rinsed and dried	100	2.0	17.0			
1/43	0	13	M	1.2%, rinsed	100	1.0	24.0			
7/43	12	11	E	1.2% + Vatsol OS .1%, 85° F., rinsed	200	3.0	0.5	200	8.0	0.5
8/43	9	14	E	1.2% + Vatsol OS .1%, 85° F., rinsed	200	10.5	0	200	50.0	0.5
8/43	9	14	M	1.2% + Vatsol OS .1%, 85° F., rinsed	200	1.5	1.0	200	53.0	0
8/43	9	14	M	1.2% + Vatsol OS .1%, 85° F., rinsed	200	10.5	0	200	39.0	0.5
9/43	9	14	E	1.2% + Vatsol OS .1%, 85° F., rinsed	200	1.0	0.5	200	16.0	1.5
9/43	9	14	M	1.2% + Vatsol OS .1%, 85° F., rinsed	200	22.5	0	200	33.0	0
10/43	8	14	E	1.2% + Vatsol OS .1%, 70° F., rinsed	200	3.0	0.5	200	24.5	3.5
10/43	8	14	M	1.2% + Vatsol OS .1%, 70° F., rinsed	200	54.0	0.5	200	84.0	0
10/43	7	12	E	1.2%, 2 min., 75° F., rinsed	200	11.0	5.5	200	44.5	8.5
10/43	7	12	M	1.2%, 2 min., 75° F., rinsed	200	42.5	1.5	200	68.0	2.5
11/43	7	12	E	1.2%, 2 min., 85° F., rinsed	200	7.0	5.5	200	69.5	4.0
11/43	7	12	M	1.2%, 2 min., 85° F., rinsed	200	0.5	0	200	58.5	0
11/44	5	14	E	2.0% + Formalin† .4%, 70° F.‡	200	11.0	2.0	200	46.5	11.5
11/44	5	14	E	1.2%, 2 min., 65° F., rinsed	200	24.5	4.5	200	46.5	11.5
11/44	5	14	E	1.2% + Formalin† .24%, 65° F.‡	200	49.5	6.5	200	46.5	11.5
11/44	5	14	E	1.2% + Formalin† .24%, 65° F., rinsed						
Weighted averages										
Total fruits and average decay (Eureka rinsed)					1600	25.4	1.4	1400	46.9	2.2
Total fruits and average decay (Meyer rinsed)					1000	4.7	2.6	1000	41.5	3.5
Total fruits and average decay (all lots)					3500	14.4	4.0	3000	41.6	4.2
Comparable summer and fall treatments Aug. to Nov., 1943	Dowicide A alone, Eureka				400	48.2	1.0	400	76.0	1.2
	Dowicide A with added Vatsol, Eureka				600	17.8	0	600	40.7	0.3
	Dowicide A alone, Meyer				400	9.0	5.5	400	57.0	6.2
	Dowicide A with added Vatsol, Meyer				600	1.8	0.7	600	31.2	1.7

*E—Eureka; M—Meyer.
†Formaldehyde 37%.
‡These lemons showed injury in form of browned areas on surface and some sunken areas.

No tests were conducted with sodium ortho-phenylphenate 1.2% in the water phase of a water-wax emulsion at 100° F., which has been reported by Brooks (2) and more recently by Winston (correspondence) as giving good control without the hazard of chemical injury to fruit. It would seem well established that this method for treatment with Dowicide A is safe and reliable. It should not be used before coloring, however, as the wax coating greatly retards yellowing in the coloring room.

Ineffective chemicals

Among the many chemicals tried by the fruit-dip method, several did not show promise at the concentrations tested. The treatments showing more than 10% decay are as follows:

G-4-40, monosodium salt of 5-chloro-2-hydroxyphenyl methane, 1% aqueous.
G-11, bis-(3,5,6-trichloro-2-hydroxyphenyl) methane, 0.5 and 0.2%.
Copper sulphate, 0.125% (resulted in apparent stimulation of stem-end decay).
Dihydroxydiphenyldimethyl methane, 1.2%.
Diphenylamine, saturated aqueous.
Dithane, liquid, ½ and 1%.
Fermate (ferric dimethyl dithiocarbamate), 0.125%.
Hyamine 1622, 25% aqueous, (di-isobutylphenoxyethoxyethyl dimethyl benzyl ammonium chloride), at 0.2, 0.4 and 1%.
8-Hydroxquinoline, 0.01%.
8-Hydroxy quinoline sulphate, at 0.5, 0.75 and 1%.
Iodine in potassium iodide sol., 0.02 to 0.04%, each in 3 times the concentration of potassium iodide (KI).
Roccal (brand of Benzalkonium chloride, Winthrop Chemical Co., Inc.), 0.2 to 1%.
Salicylic acid, 0.25%, and same in alcohol 0.2%.
Santobrite (sodium pentachlorophenate), 1%. 4 and 9.5% decay, with checks over 40%.
Sodium dimethyldithiocarbamate, 0.2%.
Sodium hypochlorite, 0.75 to 2% as Cl (chlorine).
Isothan, 0.2%.

Diphenyl Tissue Wraps as Supplemental Treatment

A series of tests were conducted in the summer, fall and winter of 1943 and in the fall of 1944 to test the efficiency of diphenyl-impregnated tissue fruit wraps for stem-end rot control. They were used both with and without initial fruit-dip treatments. The benefits obtained were substantial in the summer and fall tests when stem-end rot is normally high. In a series of 7 tests with Metbor on both Eureka and Meyer lemons, there was an average of 11.7% stem-end decay with plain wraps and only 2.8% with diphenyl wraps. In tests with Dowicide A treatments there were averages for Eureka and Meyer together of 7.46% stem-end decay in plain and 4.0% in diphenyl wraps. In the check lots, without prior treatment, there

Table 5. Comparisons between diphenyl and plain wraps for the control of decay in lemons

Date of test	Test period, days: No wraps, color room	Test period, days: Wraps, at room temp.	Variety*	Treatment prior to coloring	Diphenyl Wraps: No. of fruits	Diphenyl Wraps: Decay, percent: Diplod.	Diphenyl Wraps: Decay, percent: Penic.	Plain Wraps: No. of fruits	Plain Wraps: Decay, percent: Diplod.	Plain Wraps: Decay, percent: Penic.	Percent reduction of decay due to diphenyl: Diplod.	Percent reduction of decay due to diphenyl: Penic.
7/43	12	11	E	All fungicidal dips	800	0.6	1.6	800	4.1	4.2	85.4	61.9
7/43	12	11	E	Check (no dip)								
8/43	9	14	E	All fungicidal dips	800	8.6	2.2	800	9.2	1.1	6.5	—100
8/43	9	14	E	Check (no dip)	200	34.0	1.5	200	50.0	0.5	32.0	—200
8/43	9	14	M	All fungicidal dips	800	4.5	0.4	800	6.5	1.2	30.7	66.7
8/43	9	14	M	Check (no dip)	200	30.2	1.5	200	53.0	0	43.7	—†
9/43	9	14	E	All fungicidal dips	800	2.6	0.7	800	10.1	0.6	74.3	—16.7
9/43	9	14	E	Check (no dip)	200	6.5	1.0	200	39.0	0.5	83.3	—100
9/43	9	14	M	All fungicidal dips	800	0.9	1.1	800	3.0	1.1	70.0	0
9/43	9	14	M	Check (no dip)	200	3.0	0	200	16.0	1.5	81.2	100
10/43	8	14	E	All fungicidal dips	800	3.5	0.7	800	28.4	0.5	87.7	—40
10/43	8	14	E	Check (no dip)	200	0.5	0	200	33.0	0	98.5	0‡
10/43	8	14	M	All fungicidal dips	800	1.2	2.6	800	13.1	4.9	90.8	46.9
10/43	8	14	M	Check (no dip)	200	2.5	1.5	200	24.5	3.5	89.8	57.1
12/43	5	15	E	All fungicidal dips	504	1.6	11.2	504	1.6	44.1	0	74.6
12/43	5	15	E	Check (no dip)	252	5.2	17.8	252	1.2	71.0	−333.3ᵀ	74.9
11/44	5	14	E	All fungicidal dips	1000	21.9	3.3	1000	25.2	4.4	13.1	25.0
11/44	5	14	E	Check (no dip)	200	44.0	13.0	200	46.5	11.5	5.4	—13.0
Total fruits and average decay, dipped Eureka					4704	7.4	2.8	4704	14.3	6.8	48.3	58.8
Total fruits and average decay, check Eureka					1052	17.4	7.2	1052	25.7	18.3	32.3	60.7
Total fruits and average decay, dipped Meyer					2400	2.2	1.4	2400	7.5	2.4	70.7	41.7
Total fruits and average decay, check Meyer					600	11.8	1.0	600	31.2	1.7	62.2	41.2

*E is Eureka; M is Meyer.
†A negative reading occurs here; the value is indeterminate since no Penicillium decay occurred in the plain-wrap lot.
‡Indeterminate; no Penicillium decay occurred.
ᵀWhile the negative figure here appears large, the actual incidence of stem-end decay in the diphenyl wrap is low; and the still lower figure for plain-wrap is probably due to error in the reading (see text).

was an average of 31.9% decay in plain and 11.0% in diphenyl wraps. The results with all fungicidal dips, with and without diphenyl wraps, are recorded in Table 5.

The results shown in the columns of averages, Table 5, indicate substantial benefit derived from the use of diphenyl wraps. With but one exception, greater reduction of stem-end rot from the use of diphenyl wrap is indicated in the last column. In that exceptional case, a winter treatment with no prior fungicidal dip, the incidence of green mold decay was very high in the plain wraps, 71%, and probably destroyed some fruits that would have developed Diplodia rot. The average of 6 treatments of Eureka lemons with "all fungicides" showed 14.3% stem-end decay in plain wraps and 7.4% in diphenyl wraps; "no prior dip" showed reduction of the decay from 25.7% in plain wraps to 17.4% in diphenyl. The average of 3 treatments of Meyer lemons with all fungicides showed 7.5% stem-end decay in plain wraps and 2.4% in diphenyl; the corresponding check lots (no prior dip) showed 31.2% in plain and 11.8% in diphenyl wraps.

While reduction of stem-end decay has been shown from the use of diphenyl wraps alone, it has not been sufficient in heavy incidence of decay to be considered as giving satisfactory commercial control. When, however, the diphenyl wrap followed a good dip treatment for control of decay, its supplementary effectiveness was usually sufficient for satisfactory commercial control.

In all the summer and fall tests reported in this bulletin, the incidence of green mold decay was so low as to be considered negligible. Results of winter tests in which green mold decay was more prominent are included in the section devoted primarily to it.

The Control of Penicillium (Green Mold) Decay

Up to this point, citrus decay of the stem-end rot type, caused in the Lower Rio Grande Valley chiefly by *Diplodia natalensis,* has been the main topic. While this is usually the main cause of loss of citrus fruits in transit and storage, there are frequently heavy losses due to the green mold, and to a less extent to the blue mold. These molds are usually not much of a factor in the summer and early fall. There is a sudden drop in the incidence of stem-end rot and a rise in green mold decay beginning in November or December. The drop in temperature in the winter months is unfavorable for the development of Diplodia but is favorable for Penicillium. The increased maturity of the fruits makes them more tender and, therefore, more susceptible to bruises and rind injuries. Most of the

tabulations in this paper give results in the control of green mold. In practically all of them, the only check lots that show green mold decay of 10% or greater are in December and January, and occasionally in November and February.

There are indications in some of the tables that certain chemicals are of high value for controlling green mold. Results occasionally were inconsistent. In one November test with 4% borax (Table 2) in which there was 19.5% green mold decay in the check, there was a considerably higher percentage in the treated lot. Metbor at 5%, in a December test (Table 3), showed only 3% green mold, and Metbor with iodine added showed 2%, when the check gave 10.5% green mold. Green mold rot was 6% in another treatment in the same test when the fruit was rinsed afterward. In a January test, next in the series with Metbor, the treatment showed 13% decay, with 19.5% in the check; and in an identical treatment followed by a standard waxing, the decay was 26% which was higher than the check. In one other winter test, with the check showing 47% green mold decay, the addition of the wetting agent Vatsol did not add to its effectiveness. In general, there was never any indication that the addition of Vatsol or Vatsol and iodine at 0.02% (in potassium iodide solution) contributed to the effectiveness of the Metbor treatment. In a December test with 1% Dowicide A, there was 5% green mold (Table 4), with the check showing 10.5% decay; but when the treatment was followed by rinsing in tap water to prevent chemical injury there was 25% green mold decay, as compared with 19.5% in the checks. In a January treatment with 1.2% Dowicide solution, rinsed, there was 24% decay while the check showed 19.5%. In a November 1944 treatment of the same kind, there was 2.0% decay, with 11.5% in the check. These results in general indicate borax, sodium metaborate and sodium ortho-phenylphenate when used alone are rather unreliable for the control of green mold.

Several experiments were conducted in an attempt to reduce Penicillium decay to a point below that obtained with the standard chemical treatments.

Diphenyl-impregnated tissue wraps for green mold control

Most of the tests with diphenyl wraps were made in the summer and fall when green mold was not a serious factor. In the series of 7 tests including both Eureka and Meyer lemons, there was an average of 2.5% green mold in the plain wrap as compared with 1.5% in the diphenyl wrap. Referring to Table 5, recording "all fungicidal dips" as against no dip, in the December 1943 test which

alone shows severe green mold decay, there was a reduction from 44.1% to 11.2% due to the use of diphenyl wrap. There was 52.7% green mold in plain wraps and 10.7% in diphenyl following a standard Metbor treatment.

The value of diphenyl was further demonstrated in tests with another method of application in 1946. Diphenyl was applied in the form of impregnated pads each consisting of 8 sheets of wrapping tissue 12 by 24 inches in dimensions, which were placed in the bottoms, between each packed layer and on the tops of the packed crates. The fruit was not especially treated for control of decay but went through the regular commercial washing process followed by drying and waxing, and was packed non-wrapped. The temperature range during the 2-week holding period was mostly 50° to 60° F. With Temple oranges there was only a slight reduction in green mold, 7.0% in the check and 5.5% in the diphenyl-pad crate. The corresponding reduction was from 17.6% to 7.9% with pineapple oranges, which had received the color-added processing.

Diphenyl alone appears beneficial in that it greatly reduces the incidence of green mold; but its greatest practical value is as a supplement to a beneficial fruit-dip treatment. Here a consistent additional reduction of green mold as well as of stem-end rot occurs.

Fumigation with Nitrogen Trichloride (Decco)[1]

Considerable experimental work was done during the fall and winter of 1946 with nitrogen trichloride gas for the control of decay in lemons. The detailed results of this work are reported in a separate paper (17). The gas, in concentrations of from .007 to .04 parts per million, was used in the coloring room for periods of 2 to 6 hours per treatment. The first fumigation was given as soon as possible after the fruit was placed in the coloring room. Subsequent treatments were spaced 24 to 48 hours apart depending on the length of the coloring period. While the nitrogen trichloride treatment alone did not always give adequate control of stem-end rot, it did reduce the incidence of this decay considerably. When used following chemical dips, it added to the degree of control obtained with the dip alone. In cases where such dips as sodium metaborate and quaternary ammonium compounds alone were not sufficient, the addition of nitrogen trichloride treatments in the coloring room brought about satisfactory control. The combination of chemical dip immediately after harvest followed by nitrogen trichloride treat-

[1]The Decco process and equipment for its application are produced by Wallace & Tiernan Sales Corp., 3630 East Colorado St., East Pasadena, California.

ment in the coloring room appears to be a practical method of materially reducing the hazard from stem-end rot and green-mold rot in lemons.

RECOMMENDATIONS

Even though the type of decay in lemons varies with the season, Diplodia stem-end rot being the principal factor in the summer and fall, and blue and green molds in winter, the treatments recommended are the same throughout the harvest season, from June to January and February harvests. When a prolonged coloring (degreening) period is required for early-harvested fruits any treatment involving the use of wax must be deferred until after the fruits are yellow. Late lemons that are already well colored can be waxed immediately after treatment. The successive steps for all lemons are as follows:

1. Use extreme care to avoid bruising or breaking the rinds at all stages of handling, including picking, placing in lug boxes, hauling to the packing shed, dumping, dipping, re-boxing, stacking in the coloring rooms, and finally the various handling procedures up to packing and shipping. Initial dipping treatments should be given as soon as possible after harvesting and hauling from the field to the packing house.

2. The freshly harvested fruits are dumped from lug boxes into the dipping tanks where they receive a 1 to 2-minute soak in one of the following solutions, at room temperature:

a. Sodium metaborate (Metbor), 4.5 to 5 percent.

b. Sodium ortho-phenylphenate (Dowicide A), 1.2 percent, with wetting agent added, Vatsol OS at 0.1%. The fruits must be rinsed before stacking in the coloring room in order to avoid the slight chemical burning that occurs otherwise.

3. The next step may be a choice between 3 entirely different treatments.

a. While in the coloring room the lemons may be subjected to nitrogen trichloride gas (Decco Process) by injecting a minute quantity of the gas, 0.03 parts per million, into the room from one to three times, for about 4 hours each treatment.

b. After coloring, repeat treatment No. 2 above, then follow immediately with a wax-emulsion treatment by one of the various means available, with Dowicide A at 1.2 percent in the water phase of the emulsion.

c. After treatment No. 2, *a* or *b*, and after the fruits are well colored, follow with a regular waxing treatment, then wrap the fruits individually with diphenyl wraps.

In the experiments reported in this bulletin the recommended treatments have consistently reduced decay from percentages ranging from 10 to 85 percent down to from 0 to 5 percent. Where the chemical-dip treatment alone has not been satisfactory, as in some seasons of high incidence of decay, the supplementary treatments suggested have almost invariably brought control of decay into a satisfactory range. The supplementary treatments are especially recommended for Eureka lemons with which the chemical-dip treatment alone has frequently failed to give satisfactory control.

Precaution. It is never wise to wash fruits unless a disinfectant is contained in the wash water. To do so is very apt to increase the amount of decay, particularly green mold, over what would occur in dry-processed fruits.

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